

5.0 Contaminant Fate and Transport

This section provides an analysis and discussion of physical and chemical processes that control the fate and transport of site contaminants. This discussion takes into account the physical setting of the site, the interaction of the surface and ground water hydrology, the previous industrial operations at the site, the nature of the chemical compounds encountered during the sampling and analysis program, and any apparent trends in the distribution of contaminants. This section provides a discussion of the physical, chemical, and biological characteristics of chemical compounds of concern, and a discussion of the sources, pathways and receptors for those chemical compounds associated with the site.

5.1 Contaminants of Concern

A wide range of contaminants were identified during the investigation, including volatile organic compounds (VOCs); semi-volatile organics (SVOCs), particularly polyaromatic hydrocarbons (PAHs); several heavy metals; pesticides; and dioxins.

Based on the site history and results of previous investigations, the primary chemicals of concern during the recent investigations are those presumed to be associated with tannery operations (e.g., metals, dioxins, phenols, and oils); textile operations (e.g., metals and solvents) and incidental fuel storage (e.g., PAHs). In addition to potential human and environmental risks posed by these compounds, available information indicated that those compounds were likely to exist onsite in significant concentrations.

Tables 5.2-1 through 5.2-5 presents lists of contaminants detected during the Remedial Investigation. The tables are organized by major contaminant classes (e.g., VOCs, SVOCs, etc.) and each table, where applicable, is divided into subclasses (e.g., halogenated VOCs and non-halogenated VOCs).

5.2 Factors Affecting Fate and Transport

Tables 5.2-6 through 5.2-10 present the important fate and transport parameters for the site contaminants.

A number of physical, chemical, and biological processes are known to impact upon the fate and transport of environmental contaminants. In addition to the individual effects of each such process, there is much interaction between them. Interaction of one process may limit the impacts of another on the same target compound. The principal factors affecting environmental fate and transport of chemical contaminants are briefly described below.

5.2.1 Solubility

Solubility is the measure of a chemical's ability to dissolve in water and is expressed in units of chemical mass/unit volume of water (e.g., ug/L or mg/L). Aqueous solubility is an important determinant of chemical concentration and residence time in water. Highly soluble chemicals dissolve readily in water and remain in solution. In addition, highly soluble compounds are less

likely to volatilize from water and are more likely to biodegrade (Montgomery, 1991). Chemicals exhibiting low solubility tend not to remain in solution due to adsorption and/or precipitation. In addition to the impact upon contaminant transport, solubility will directly affect the rate of leaching of chemicals from contaminated wastes or soils.

5.2.2 Volatilization

Volatilization describes the movement of a chemical from the surface of a liquid or solid matrix to a gas or vapor phase. Only the neutral (uncharged) form of a compound can volatilize. Volatilization rates are affected by soil properties, vapor pressure, temperature, and sorption. VOCs partition between the aqueous and gaseous phase in unsaturated soils. This process will occur most readily for compounds with a high vapor pressure and a high Henry's Law Constant Value (H). Volatilization is a particularly important environmental fate and/or transport process for chemicals exhibiting low aqueous solubility and polarity.

VOCs in the saturated zone or in surface water will partition to the gaseous phase, particularly those with lower solubility (e.g., xylenes). VOCs with greater aqueous solubility (e.g., benzene) show a relatively greater tendency to remain in solution. Note that the effectiveness of volatilization normally decreases with depth in the soil column.

Volatility of a compound increases with increasing vapor pressure. Lyman et al., (1982) describes compounds as "readily," "significantly," or "limitedly" volatilized based on the values of their Henry's Law Constants. For example, a compound with H values less than 1.0×10^{-5} (e.g., dimethyl phthalate pyrene) has a low degree of volatility, and those with H values below 3.0×10^{-7} are considered non-volatile (PCBs). H values between 1.0×10^{-5} and 1.0×10^{-3} (e.g., naphthalene and phenanthrene) are moderately volatile, while those with values exceeding 1.0×10^{-3} (e.g., VOCs) are considered highly volatile.

5.2.3 Sorption

Sorption (adsorption/absorption) is usually defined as the reversible binding of a chemical to a solid matrix. However, there is evidence in the published literature that there is a partially irreversible component related to the time that the compound has been sorbed. Both soluble nonpolar and insoluble chemicals may sorb strongly to sediments, suspended soils, and soils. Sorption of these compounds limits the fraction available for other fate processes such as volatilization and/or hydrolysis.

Partition coefficients, which are measures of sorptive characteristics, define the relative concentrations of a given chemical in two phases or matrices. The tendency of organic chemicals to be sorbed is also dependant on the organic content of the soil and the degree of hydrophobicity (lack of affinity for water) of the solute (contaminant).

The rate of travel for each chemical depends on the ground water seepage velocity and the degree of sorption. If an organic chemical is extensively adsorbed by particles, it will be rendered relatively immobile. The rates and degree of volatilization, photolysis, hydrolysis, and biodegradation are directly dependant on the extent of adsorption (Montgomery, 1991). The

vadose zone typically contains greater amounts of organic material and metal oxides (which may also act as sorbents) than the saturated zone, which may make the rate of movement in the vadose zone substantially less than that in the saturated zone (USEPA, 1989a).

Partition coefficients are expressed as concentration ratios between two phases. Partition coefficients useful in describing the environmental behavior of chemical contaminants include K_{ow} , K_d , and K_{oc} , and are defined below.

- **K_{ow}** (Octanol-water partition coefficient): the ratio of the chemical concentration in octanol (organic solvent) to that in water, at steady state conditions. The octanol serves as a surrogate for lipid or other organic phases.
- **K_d** (Distribution Coefficient): the K_d parameter is important in estimating the potential for the adsorption of dissolved contaminants in contact with soil. As typically used in fate and contaminant transport calculations, the K_d is defined as the ratio of the contaminant concentration associated with the solid to the contaminant concentration in the surrounding aqueous solution when the system is at equilibrium.

For example, the most conservative estimate of contaminant migration through the subsurface natural soil is to assume that the soil has little or no ability to slow (retard) contaminant movement (i.e., a minimum bounding K_d value). Consequently, the contaminant would migrate in the direction and, for a K_d value of ≈ 0 , travel at the rate of water. To estimate the maximum risks (and costs) associated with onsite remediation options, the bounding K_d value for a contaminant will be a maximum value (i.e., maximum retardation).

The K_d value is usually a measured parameter that is obtained from laboratory experiments. Ideally, site-specific K_d values would be available for the range of aqueous and geological conditions in the system to be modeled. Values for K_d not only vary greatly between contaminants, but also vary as a function of aqueous and solid phase chemistry.

- **K_{oc}** (Organic carbon-water partition coefficient): the K_d normalized to the concentration of organic carbon in the solid phase. High K_{oc} values usually indicate a high tendency of a compound to sorb to the organic soil matter. Chemicals with a K_{oc} greater than 10,000 will adsorb strongly to soil organic carbon (e.g., fluoranthene, phenanthrene, and pyrene). Chemicals with a K_{oc} ranging from 1,000 to 10,000 will moderately adsorb, and move slowly in the soil profile (e.g., naphthalene). Chemicals with a K_{oc} of less than 1,000 weakly adsorb to soil organic carbon and tend to be more mobile. Examples of weakly adsorbed compounds include many VOCs such as benzene and xylene.

5.2.4 Hydrolysis

Hydrolysis refers to the chemical breakdown reaction involving the water hydrogen ions (H^+) and hydroxyl radicals (OH) associated with water. The result of hydrolytic reaction is the subsequent breakdown and/or modification of the compound. The extent of chemical hydrolytic

reactivity depends upon both pH (acidity/alkalinity) and the molecular structure of the specific target chemical.

5.2.5 *Photolysis*

Photolysis refers to the decomposition process induced by radiant energy (sunlight) on target compounds. Specifically, photochemical breakdown processes involve structural changes in a molecule induced by radiation in the ultraviolet-visible light range. The rate of decomposition of a chemical from photochemical reactions depends on its molecular structure, the proximity and character of the light source, and the presence of other reactant compounds. This process may occur in surficial soils at the Pownal Tannery Superfund Site, but would not affect contamination in the subsurface soils.

5.2.6 *Oxidation/reduction*

Oxidation/reduction are chemical reaction processes that involve the removal or addition of electrons from, or to, a target compound. Both oxidation and reduction reactions are environmentally significant in that they influence the mobility and fate of chemicals in environmental matrices. Oxidized and reduced forms of the same chemical compound may exhibit entirely different chemical, ecological and/or toxicological properties.

In general, substituted aromatic compounds such as ethylbenzene and naphthalene can be oxidized. Oxidation rates for aromatic compounds are typically an order of magnitude faster than for chlorinated aliphatic compounds (e.g., 1,2-dichloroethane [1,2-DCA]). Overall, abiotic (without biological life) oxidation of organic compounds in ground water systems is limited.

5.2.7 *Bioaccumulation*

Bioaccumulation refers to the accumulation and transport of chemical compounds by living organisms resulting from tissue absorption levels exceeding the chemical that is ingested that may be further concentrated through the food chain. Potential for bioaccumulation is quantified by bioconcentration factors (BCFs), which define the ratio of the concentration of a compound in animal or plant tissue to that found in the immediately-surrounding environment (ambient air, water or soil). BCFs generally tend to underestimate the potential contaminant concentration in the organism. Organic chemicals with high BCFs (such as pesticides) are typically insoluble in water and lipophilic (attracted to liquids) and, thus, tend to remain in animal fat tissue. Some heavy metals, such as mercury, may also be bioaccumulated. BCF values presented in the literature most commonly pertain to fish species.

5.2.8 *Biotransformation/Biodegradation*

Biotransformation/biodegradation refers to the biologic conversion of chemical compounds to other products. Many microorganisms and biota are resistant to, or develop resistance, to specific chemicals (particularly organic chemicals) and can metabolically transform those compounds to products that may or may not be as toxic as the original compounds. Biological transformation includes a variety of enzyme-catalyzed reactions such as oxidation and reduction.

Variables affecting the rate of biodegradation include the following.

- Number of microorganisms
- Chemical properties, concentrations, and distribution
- Presence of food and nutrients
- Temperature
- pH
- moisture and oxygen content

The rate of biodegradation tends to be higher for low molecular weight compounds. Naturally occurring soil and aquatic microorganisms capable of degrading aromatic hydrocarbons (e.g., BTEX) have been studied, and a relationship between dissolved oxygen and biodegradation has been documented (Jamison, et al., 1975; and Bailey, et al., 1973). As the aromatic hydrocarbons are mobilized by dissolution from soil or sediment, they are likely to be rapidly degraded as long as microorganisms and dissolved oxygen are available. Degradation rates for aromatic hydrocarbons are much slower under anaerobic conditions.

5.3 Characteristics of Site Contaminants

This section summarizes the chemical characteristics and expected environmental fate and transport behavior of organic and inorganic chemicals of concern associated with the Pownal Tannery Superfund Site. The organic constituents of concern are grouped into five general classes; these are volatile organics, semi-volatiles, pesticides, and dioxins. Inorganics of interest consist of metals and cyanide. Sources of these site contaminants, and a brief account of their presence at the site, are discussed as well as anticipated environmental fate of each chemical class.

5.3.1 Halogenated Volatile Organic Compounds

Halogenated volatile organic compounds were detected in ground water, surface soils, subsurface soils, lagoon sludge, surface water and sediment sampled during the site investigation.

Halogenated compounds were detected most prominently in lagoon sludge/soil, but also in site aqueous media water (surface water and ground water). In general, halogenated volatile organics are widely used as solvents, degreasers, dry-cleaning agents, refrigerants, and chemical intermediates. Due to their widespread use in many industrial settings, chlorinated solvents are often found in the environment, originating from numerous point and non-point sources.

Sources and Background: The site specific industrial processes that led to the generation of halogenated VOC wastes at the Pownal Tannery Superfund Site are not specifically known. However, the halogenated volatiles detected during the site investigation may have originated from several sources. Some of the halogenated compounds detected at the site are components of, or used in the manufacture of, products used to degrease leather during the cleaning process prior to tanning, as well as coatings to be applied following tanning (e.g., lacquer top-coatings, carriers for colorants, and dyes). In addition, the presence of organic compounds such as

trichloroethylene in the site subsurface may be a result of site activities such as incidental spills, solvent usage, pesticides, and carrier solvents.

Solubility: In general, these compounds exhibit moderate to high solubility in aqueous matrices (e.g., 10 mg/L for 1,1,2-trichloro-1,2,2-trifluoroethane [Freon-113] to 20,000 mg/L for methylene chloride). Considering their soluble nature in water, surface runoff and ground water movement are expected to be an important fate and transport processes, however, the bulk of halogenated VOCs were detected in subsurface lagoon sludge/soil. Consequently, surface runoff appears to be a lesser factor at this site.

Volatilization: The halogenated volatiles detected at the site possess wide-ranging volatility. Certain compounds are quite readily transported into the atmosphere from surficial soil and water matrices. Vapor pressure ranges from 1 mm Hg for 1,2-dichlorobenzene to 4,310 mm Hg for chloromethane. As a result, volatilization of these compounds from near-surface sources is expected to be an environmental fate process at this site; however, the number of non-halogenated VOCs detected in surface soils and the concentrations detected are both small. Lagoon sludge/soil and other subsurface sources, where the concentrations of this class of compound are much greater, will not be as readily impacted by this mechanism.

Sorption: Adsorption to soils/sediments or organic matter is not expected to greatly affect halogenated volatile organic compounds. Non-halogenated organics generally have low affinity for organic matter as illustrated by the low organic carbon/water partition coefficients (K_{oc}) (e.g., 8.8 [methylene chloride] to 439 [carbon tetrachloride] ml/g) and octanol/water partition coefficients (K_{ow}) values for many such compounds. However, several exceptions apply to compounds such as 1,2-dichlorobenzene and 1,2,4-trichlorobenzene which have K_{oc} values of 1,700 ml/g and 9,200 ml/g, respectively. Nonetheless, these values are significantly less than those characteristic of many PAHs, which are characterized by strong partitioning to solid organic phases. In general, low K_{oc} values coupled with high water solubility and volatility, make adsorption a relatively minor environmental fate process for these compounds compared to other mechanisms.

Bioaccumulation: Available bioaccumulation data suggests that bioaccumulation can occur with chlorinated hydrocarbons, but to a lesser degree relative to other compound types. Bioconcentration factors tend to be lower than those compounds with documented bioaccumulative tendencies (e.g., benzo(a)anthracene). For example, bioconcentration factors expressed as log BCF, for trichloroethylene range from 1.025 to 3.06, depending upon the organism, with 3.06 representing an extreme value for a particular organism (Mackay et al 1993). In contrast, the bioconcentration factors for benzo(a)anthracene range from 2.54 to 5.0. (Mackay et al 1992) In addition, research suggests that a directly proportional relationship exists between the BCF and the octanol-water partition coefficient. (Mackay 1982) Overall, octanol-water partition coefficients for chlorinated VOCs tend to be significantly lower than those of known bioaccumulative compounds such as certain pesticides, PCBs, dioxins, furans, and polyaromatic hydrocarbons. Consequently, bioaccumulation is not expected to be a significant factor for halogenated VOCs at this site.

Biodegradation/Biotransformation: Once in the subsurface, the chlorinated VOCs may undergo reductive dehalogenation. For example, PCE may be progressively broken down to TCE, cis-1,2-DCE, vinyl chloride, and, ultimately carbon dioxide. However, the time required for each step may vary widely and degradation may or may not occur. Several studies report that the isomer cis-1,2-DCE is formed preferentially to trans-1,2-DCE. One possible explanation is that during reductive dechlorination, a chloride ion and free radical are formed. Because water is typically the medium in which the reaction occurs, the most polar form of the radical is favored (cis-1,2-DCE). Vinyl chloride forms from the reductive dechlorination of cis-1,2-DCE. Vinyl chloride was detected in ground water samples, but at low concentrations and at much lower frequency than PCE or TCE.

Furthermore, the relative rate of dechlorination of these chlorinated VOCs decreases as chloride atoms are sequentially removed from the molecule. Therefore, the rate of degradation of PCE and TCE is more rapid than that of the 1,2-DCE isomers, and reductive dechlorination of vinyl chloride may not be observed. As such, vinyl chloride is relatively persistent in anaerobic environments and the formation of carbon dioxide or ethylene is rather slow. In contrast, if the ground water conditions downgradient become aerobic, degradation of DCE and vinyl chloride may occur rapidly. Carbon dioxide is the general end product of organic degradation (i.e., oxidation).

Hydrolysis: Trichloroethylene hydrolysis has been reported, but the measured rate constants imply an environmental half-life at pH 7 and 25°C of 100,000 years. Similarly, long half-lives have been calculated for other halogenated ethenes, so that, as a class, hydrolysis can be disregarded for these compounds (Boethling and MacKay, 2000).

Photolysis: Photolysis is not very significant in aquatic systems for chlorinated VOCs, and is not likely to be a significant fate process at this site. (EPA 1979) For example, trichloroethylene has been shown to not undergo direct photoreactions at significant rates. (Boethling and Mackay 2000).

Oxidation: Direct oxidation of these compounds is generally an insignificant process in natural environments (EPA, 1979).

Chlorinated VOCs tend to have high solubility's relative to their MCLs, moderate to high volatilities, low to moderate partition coefficients, high mobilities, and densities greater than water. As a result, they are relatively easily volatilized into the atmosphere (if conditions are suitable), or can be leached from soil into ground water. The fate of chlorinated VOCs in soil and ground water is a function of the solubility, volatility, sorption, and degradation. Because of their high volatility, moderate to high solubility relative to their MCLs, and low adsorption to soils, chlorinated VOCs are relatively mobile and nonpersistent in soil systems.

5.3.2 Non-Halogenated Volatile Organic Compounds

Sixteen non-halogenated volatiles were detected during the investigation including 2-butanone, carbon disulfide, methyl acetate, xylene (total), 1-2-dimethyl-4-ethylbenzene, 2-hexanone,

acetone, benzene, cyclohexane, ethylbenzene, isopropylbenze, methyl tert-butyl ether, methylcyclohexane, styrene, and toluene. These compounds can be associated with other industrial uses, but they are also associated with leather cleaning and tanning processes. Three of the compounds, acetone, 2-butanone, and methyl chloride are common laboratory contaminants. In general, these compounds were detected in lagoon sludge/soil and to a significantly lesser degree in surface and subsurface soil, ground water, surface water, and sediment.

Sources and Background: The non-halogenated volatiles detected during the site investigation may have originated from several sources. Some of the non-halogenated compounds detected at the site are components of, or used in the manufacture of, products used to clean and treat leather during the cleaning process prior to tanning, such as enzymes, detergents, de-hairing and conditioning solutions, coatings to be applied following tanning. In addition, the presence of organic compounds such as benzene in the subsurface may be a result of site activities such as incidental spills and solvent usage.

Solubility: In general, these compounds exhibit high solubility in aqueous matrices (e.g., 152 mg/L for ethylbenzene to 268,000 mg/L for 2-butanone). Considering their highly soluble nature in water, surface runoff and ground water movement are expected to be a principal fate/transport process. However, the number of non-halogenated VOCs detected in surface soils and the concentration detected are both small.

Volatilization: Non-halogenated volatile organic compounds tend to be highly volatile and therefore are readily transported into the atmosphere from surficial soil and water matrices. Vapor pressures range from 5.0 mm Hg for styrene to 297 mm Hg for carbon disulfide. As a result, volatilization of these compounds from near-surface sources is expected to be an environmental fate process at this site; however, the number of non-halogenated VOCs detected in surface soils and the concentration detected are both small. Non-halogenated VOCs identified in lagoon sludge/soil and other subsurface sources will not be as readily impacted by this mechanism.

Sorption: Adsorption to soils/sediments or organic matter is not expected to greatly affect these organic compounds. Non-halogenated VOCs generally have low affinity for organic matter as illustrated by the low K_{oc} values (e.g., 4.5 [2-butanone] to 132 [benzene] ml/g) and low K_{ow} values for many such compounds. Ethylbenzene and xylene, however, are exceptions, exhibiting K_{oc} values of 1,410 and 1,830 ml/g, respectively. In general, low K_{oc} values coupled with high water solubility and volatility, make adsorption a relatively minor environmental fate process for these compounds compared to other mechanisms.

Bioaccumulation: In general, these compounds do not bioaccumulate appreciably in aquatic organisms. Further, the investigations of surface water and sediment did not identify non-halogenated VOCs in these media. In addition, ecological surveys did not identify significant target species that may bioaccumulate such chemical compounds. Therefore, bioaccumulation is not expected to provide a significant environmental fate process for these identified compounds.

Biodegradation/Biotransformation: Although degradation of these compounds via microbial activity or biologic processes can occur in higher organisms, the process is generally slow (EPA, 1979). However, biologic processes are expected to provide a continuing mechanism for gradual degradation of site-derived VOCs.

Hydrolysis: Hydrolysis of these compounds does not generally occur (Clement Associates, 1985; EPA, 1979); therefore this process would not be expected to impact the fate/transport of the non-chlorinated volatiles.

Photolysis: Direct photo-disassociation within aqueous and/or atmospheric matrices is typically insignificant (Clement Associates, 1985; EPA, 1979). Further, inaccessibility of radiant energy to the primary areas contaminated by these compounds (i.e., the subsurface lagoon sludge/soil) would restrict the potential impact of this process.

Oxidation: Direct oxidation of these compounds is generally an insignificant process in natural environments (EPA, 1979).

In summary, the non-halogenated volatile organics associated with the site tend to be mobile and not particularly persistent in the environment due to their high volatility, low adsorption to soils, high water solubility, and limited capacity for bioaccumulation.

5.3.3 Acid Extractable Semi-Volatile Organic Compounds

Acid extractable semi-volatile compounds were prevalent in environmental matrices associated with the Pownal Tannery Superfund Site, especially surface soil and lagoon sludge/soil. A number of these compounds were detected including 2,4-dimethylphenol, 4-methylphenol, 4-nitrophenol, pentachlorophenol and phenol. A synopsis of the important characteristics affecting the environmental fate of this class of compounds is presented below.

Sources and Background: Acid extractables consist primarily of phenolic compounds. Phenols are a diverse group of chemicals whose structure is comprised of a basic benzene ring and one or more hydroxyl (OH) groups. However, polyphenolic extracts are also associated with alternatives to chromium leather tannage, especially for leathers intended for shoe soles, insoles, belting, straps, and specialty leather products (EPA, 1996a). Synthetic organic tannage processes have also been developed, which may account, in part, for the wide range of organic chemicals detected at this site. Acid extractable compounds were primarily detected in lagoon sludge/soil and occasionally in river sediment.

Solubility: Acid extractable semi-volatile organic compounds exhibit relatively high solubility in aqueous matrices. This is due primarily to the polarity imparted to these molecules by their functional groups, particularly the alcohol group. Phenol, for instance, has an aqueous solubility of 82,000 milligrams per liter (USEPA, 1986; Clement Associates, 1985; Verschueren, 1983). Considering the highly soluble nature of these compounds in water, transport via surface and ground water is possible; however, acid extractables have not been detected in aqueous matrices at this site.

Volatilization: Semi-volatile acid extractable organic compounds are capable of volatilizing, but this process generally proceeds at a much slower rate than for the lighter molecular weight volatile organic compounds. For example, the Henry's Law constant for phenol, a typical acid extractable compound detected at this site, is 4.54×10^{-7} atm-m³/mole. As a result, volatilization is expected to play a minor role in the environmental fate of these compounds onsite.

Photolysis: In general, direct photolysis and/or photooxidation via hydroxyl radicals can occur for the phenolic acid extractable compounds in aqueous and/or atmospheric matrices (Clement Associates, 1985; USEPA, 1979). However, these processes usually proceed at a slow rate and typically occur in aerobic environments. These processes are most likely not significant environmental fate process for this class of compounds at the site due to the generally anaerobic conditions observed in site ground water and the absence of these compounds in surface water and ambient air.

Oxidation: Oxidation of acid extractable compounds associated with the site may occur via hydroxyl radicals in aqueous and/or atmospheric matrices and/or metal-catalyzed oxidation in aerobic matrices (USEPA, 1979). As a result, oxidation may be an important environmental fate process for those compounds associated with the Pownal Tannery Superfund Site.

Hydrolysis: In general, based upon available data in the literature summarized by Clement Associates (1985), hydrolysis appears to be an insignificant environmental fate process for the acid extractable organics associated with the site. Limited hydrolysis may occur during sorption to clays for some compounds, but there is a general lack of data regarding this phenomenon (USEPA, 1979). Predictive methods can be applied for assembling hydrolysis for simple one-step reactions where the product distribution is known. Generally, however, pathways are known only for simple molecules.

Recent years have seen limited advances in formulating quantitative prediction correlations for hydrolysis rate constants. Fortunately, numerous experimental studies provide pH-dependant hydrolysis rate constants for one or more compounds in most classes of organics that might be of environmental concern. Estimation of reactivity by comparison with structural analogs within a given class is often the fastest and most reliable approach (Boethling and MacKay, 2000).

Consideration of the benchmark chemicals illustrates this approach. For example, anthracene and 2,6-di-tert-butylphenol have no hydrolysable functional groups, hence they cannot undergo hydrolysis. Trichloroethylene hydrolysis has been reported, but the measured rate constants imply an environmental half-life at pH 7 and 25°C of 100,000 years. Similarly, long half-lives have been calculated for other halogenated ethenes, so that, as a class, hydrolysis can be disregarded for these compounds (Boethling and MacKay, 2000).

Sorption: The acid extractable phenolic compounds associated with the site exhibit varying degrees of binding affinity to organic matter. Phenol, for example, has an organic carbon-water partition coefficient of 14.2 ml/g and an octanol-water partition of 1.46 (USEPA, 1986; Clement Associates, 1985; Verschueren, 1983). These data suggest that sorption to clay may be significant for some phenolic compounds, especially with the extensive clay deposits at this site.

Bioaccumulation: Some of the chlorinated acid extractable compounds associated with the site, such as pentachlorophenol, may bioaccumulate in aquatic organisms. Non-chlorinated phenols, however, are not readily bioaccumulated. Due to the absence of these compounds in surface water and the limited presence of these compounds in site sediment, and a relative absence of target species in the vicinity of the site, bioaccumulation of these compounds is not expected to be significant.

Biodegradation/Biotransformation: Biodegradation by microbial populations is a significant environmental fate process for some of the acid extractable compounds associated with the site. These compounds may biodegrade relatively rapidly under most conditions.

The majority of semi-volatile acid extractable organic compounds associated with the site are not expected to be persistent. Although the phenolic compounds detected onsite are water-soluble and, therefore, can be mobilized into surface and ground waters, they are not persistent in these environments due to their moderate volatility, susceptibility to microbial degradation, and variable affinity for organic matter and clays.

5.3.4 Base-Neutral Extractable Semi-Volatile Organic Compounds

A number of base neutral extractable semi-volatile organic compounds were identified during the investigation. The two primary subgroups of base neutrals detected onsite are polynuclear aromatic hydrocarbons (PAHs) and phthalate esters.

Polynuclear Aromatic Hydrocarbons (PAHs): Nineteen PAHs were detected onsite. These include naphthalene, 2-methylnaphthalene, acenaphthylene, acenaphthene, dibenzofuran, fluorine, phenanthrene, anthracene, fluoranthene, pyrene, carbozle, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene.

Sources and Background: PAHs are fused-ring compounds in which at least two carbon atoms in each ring are shared by adjacent rings. Typically, the rings are fully aromatic but some may be saturated and have fewer carbon atoms, such as the compound fluorene. Major sources of PAHs include coal tars, crude oils, and products from the incomplete combustion of organic matter. Presence of PAHs onsite is due in part to the past use/storage of fuel oil and associated leakage or surface disposal, as well as potential past use of coal at the site. Other sources which have contributed to the extent of PAH distribution on-site include certain types of oils and coatings used for the tanning and/or finishing of leather (e.g., marine oil).

Solubility: Solubilities of polynuclear aromatic hydrocarbons (PAHs) vary considerably in aqueous matrices, depending upon the molecular structure and degree of aromaticity of the compounds molecular structure. As a general rule, a decrease in the degree of aromaticity in the parent molecule results in a higher degree of water solubility. Although there are some exceptions, most PAHs are not very soluble in water. Water solubilities for the PAHs detected onsite range from 31.7 ppm for naphthalene to 5.00×10^{-4} ppm for dibenzo(a,h)anthracene (EPA, 1986). PAHs exhibiting the lowest water solubility have a high degree of aromaticity (i.e.,

greater than four or five aromatic rings). For PAHs with relatively high water solubilities (such as naphthalene), runoff and ground water transport of these compounds may be a significant fate/transport mechanism. However, naphthalene was not detected in surface water or ground water at this site. For the less soluble compounds, this transport mechanism will be less significant.

Volatilization: PAHs are capable of volatilizing; the process proceeds at a much slower rate than for the lighter volatile organic compounds. However, concentrations of PAHs detected onsite make volatilization likely when source areas are exposed. The more-volatile PAHs (i.e., naphthalene, acenaphthylene, and acenaphthene) have vapor pressures greater than 2.0×10^{-3} mm mercury, whereas the other compounds have vapor pressures ranging from 1.03×10^{-10} to 7.10×10^{-4} mm Hg. Probable carcinogenic PAHs associated with the site (benzo(a)anthracene, benzo(a)pyrene, benzo(g,h,i)perylene, chrysene, dibenzo(a,h)anthracene and indeno (1,2,3-cd)perylene) are less likely to volatilize due to their greater molecular weight and more complex structures. Based upon their low vapor pressures (i.e., less than 1.0×10^{-8}) and high affinity for adsorption to particles, these PAHs would be expected to be associated more with airborne particulates (Eisenreich et al., 1981).

Photolysis: In general, PAHs are only slightly susceptible to direct photolysis and/or photo-oxidation via hydroxyl radicals in atmospheric matrices (Clement Associates, 1985; USEPA, 1979). Also, when these photolytic reactions occur, they usually proceed at a relatively slow rate. An exception to this trend may occur with dissolved PAHs in aqueous matrices subject to sunlight (i.e., surface water), which may undergo rapid photolysis under certain conditions (i.e., high surface water clarity) (EPA, 1979). Since PAHs were not detected in stream water samples associated with the site, photolysis of dissolved aqueous PAHs is not expected to be a major fate process for these compounds.

Oxidation: Oxidation of PAHs associated with the site may occur via hydroxyl radicals in environmental matrices (USEPA, 1979; Clement Associates, 1985); however, this is generally a slow transformation mechanism. The quantities and concentrations of PAHs in the subsurface areas of the site, particularly lagoon sediment/soil, would provide a large supply of PAHs for oxidation. As a result, the oxidation of PAHs at the site is not likely to be a significant depletory of contamination.

Hydrolysis: The high concentrations of PAHs on site, especially in the lagoon area, constitute a large source of organic contaminants to water; however, PAHs are not susceptible to hydrolytic reactions (Clement Associates, 1985; USEPA, 1979). For example, anthracene has no hydrolysable functional groups (Boethling and McKay, 2000). Therefore, hydrolysis is not considered a significant environmental fate process for PAHs associated with the Pownal Tannery Superfund Site.

Sorption: The PAHs associated with the Pownal Tannery Superfund Site exhibit varying degrees of binding affinity to organic matter and soil particulates; this affinity is dependant upon their individual molecular structures. In general, the higher molecular weight PAHs are strongly adsorbed whereas the lighter PAHs (e.g., naphthalene) are less strongly sorbed (USEPA, 1979, USEPA, 1986). Therefore, adsorption to organic matter and/or soil particulates is expected to be

an important environmental fate process, particularly for the higher molecular weight PAHs at this site.

Bioaccumulation: For PAHs, bioaccumulation is usually a transitory process since most PAHs with less than five rings are readily metabolized by higher organisms (USEPA, 1979). Although PAHs were not detected in aqueous matrices at the site, the presence of PAHs in sediment at concentrations above screening criteria suggests that bioaccumulation is likely to be a mechanism for environmental fate of PAHs.

Biodegradation/Biotransformation: Biodegradation is a significant long-term environmental fate process for the PAHs associated with the site. PAHs are degraded under most conditions by microbial populations and/or metabolized by higher organisms relatively rapidly (EPA, 1979).

With few exceptions, the PAHs associated with the site will be relatively persistent in onsite soil and sediment matrices. This is primarily due to their generally low water solubility, resistance to photolytic, oxidative and hydrolytic degradation, and their high affinity for organic matter and soil particles.

Phthalate Esters: A total of four phthalate esters were detected in media samples; these include bis(2-ethylhexyl)phthalate, diethylphthalate, di-n-butylphthalate, and butylbenzylphthalate. Phthalate esters are neutral extractables which may be released into the environment as a result of various manufacturing processes. However, their common use as a plasticizing agent in plastics, leachability from those materials, and a presence as a microcontaminant in laboratory chemicals (Verschuere, 1983) make them common laboratory contaminants in the Region II CERCLA Quality Assurance Manual (USEPA, 1989).

Contamination of samples with phthalates from plastic sampling equipment may be another significant source of detected levels of phthalate esters. However, for phthalate compounds that are present in the environment, their affinity for organic matters and soils, low water solubility, resistance to photolytic, oxidative and hydrolytic degradation, and low volatility would make them relatively persistent chemical compounds.

5.3.5 Pesticides

Pesticides were detected in a number of surface soil, lagoon sludge/soil, and sediment samples. A total of 20 pesticides were detected, including 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, aldrin, dieldrin, endosulfan I, endosulfan II, endosulfan sulfate, endrin, endrin aldehyde, endrin ketone, heptachlor, heptachlor epoxide, alpha-BHC, beta-BHC, delta-BHC, alpha-chlordane, gamma-chlordane, gamma-BHC (lindane), and methoxychlor.

The presence of these compounds is notable in demonstrating the persistence of some pesticides in the environment. DDT, for example, has been banned for a number of years; its presence indicates the likelihood that it can persist. Concentrations of these pesticide residues onsite are limited.

Presence of these compounds is most likely due to the previous application on or adjacent to the

site, transport from offsite sources in the use of pesticides in hide storage/receiving areas. The chlorinated pesticides detected are highly persistent chemicals that strongly adsorb to soils and organic matter. Sorption appears to be dominant environmental process affecting the fate of pesticides. Water solubility of the chlorinated pesticides is variable due to the presence of functional radicals, polarity of the molecules and molecular structure, however, no pesticides were detected in any aqueous samples (surface and ground water). In theory, surface runoff and ground water may provide transport mechanisms for soluble compounds such as alpha-BHC, but not less-soluble compounds such as DDT (except as a sorbed component of transported soil particles).

Photolysis, hydrolysis, oxidation, and biodegradation are not likely to be major factors in determining the fate of these compounds, although all are expected to have some impact. Bioaccumulation can be significant for certain chlorinated pesticides, such as DDT, however due to the low concentrations detected and their low solubility, potential impacts from this biologic process are expected to be limited.

5.3.6 Polychlorinated Biphenyls (PCBs) and Dioxins

Dioxins were detected in all media at all study areas and are most concentrated in lagoon sludge. Three PCB isomers (Aroclor 1242, Aroclor 1254 and Aroclor 1260) were detected in a limited number of sediment samples collected from the Hoosic River. No other evidence of PCBs was identified in environmental media during the investigation.

Sources and Background: PCBs are generally associated with industrial applications in electrical equipment, particularly electrical transformers. Until the late 1970s, PCB oils were commonly used as fire-resistant dielectric fluids in high voltage transformers. As a result of their widespread use, PCBs were commonly released to the environment due to incidental spillage, contamination of maintenance equipment, etc. The presence of PCBs may also be associated with hydraulic equipment and lubricants. Their presence at the site may be due to any or all of these potential uses. However, the detection of PCBs upstream of the site suggests the existence of other sources unrelated to the site.

Dioxins were not specifically used in the tanning process but are common chemical contaminants in commercially supplied raw materials used by the tannery. Due to their persistent nature, they have accumulated in the site lagoons and in other areas.

Solubility: PCBs and dioxin represent some of the least water-soluble contaminants identified at this site. Thus, PCBs and dioxins are expected not to migrate in the dissolved phase.

Volatilization: Volatilization of PCBs has been shown to occur (Eisenreich et al., 1981). Atmospheric removal mechanisms include physically mediated wet and dry deposition, with dry deposition occurring only for PCBs attached to the particulate phase. However, this mechanism is not expected to have an impact on the fate of PCBs and dioxin at this site.

Photolysis: PCBs and dioxin may undergo photolysis in the atmosphere where they react with photochemically produced hydroxyl radicals (EPA, 1979). This is a slow process, particularly

for the more-chlorinated PCBs. However, photolytic factors are not expected to affect the ultimate environmental fate of PCBs since PCBs detected are only associated with sediments.

Oxidation: Oxidation is not considered to be a significant degradation process for PCBs or dioxins (EPA, 1979).

Hydrolysis: PCBs and dioxins are strongly bonded components that are not readily hydrolyzed (EPA, 1979).

Sorption: Adsorption to soils/sediments or organic matter is a major process controlling the environmental fate of PCBs and dioxins. Like chlorinated pesticides, high affinity for adsorption to organic matter is evident from their high partition coefficients. Water solubility and partition coefficients among different PCBs are correlated with the number of chlorine atoms on the molecule. Consequently, PCB congeners with low numbers of chlorine atoms tend to sorb less strongly than the more heavily chlorinated molecules, such as Aroclor 1254. The strong adsorptive tendencies of both PCBs and dioxins suggest that these compounds will remain bound to sediment.

Bioaccumulation: PCBs and dioxins have been shown to bioaccumulate in the adipose tissues of animal species.

Biodegradation/Biotransformation: Biodegradation of PCBs depends heavily upon both the degree of chlorination and the specific position of the chlorine atoms on biphenyl molecule (Brown et al., 1987). The more highly chlorinated biphenyls (Aroclors 1248, 1254 and 1260), have been shown to be resistant to biodegradation, therefore biodegradation is not anticipated to play a significant role in the environmental fate of the PCBs detected onsite.

PCBs and dioxins exhibit high persistence in the environment. This high persistence results from: (1) low solubility in water and air, (2) strong adsorption to soils, sediments and organic matter, (3) the recycling of volatilized PCBs and dioxins between the atmosphere, surface soils and water, (4) high tendencies to bioaccumulate and (5) relative resistance to biodegradation.

5.3.7 Inorganic Compounds

A large number of inorganic compounds were detected in environmental media samples; these included 23 metals and cyanide. Many of the metals encountered are normal constituents of natural soils or common dissolved constituents in associated aqueous matrices resulting from soil leaching (e.g., aluminum). However, a number of those metals identified were detected in concentrations in excess of those generally seen in naturally occurring soils/water. Heavy metals, which are significant due to their well-characterized potential human and environmental toxicities, were also detected in site soil and water samples and at concentrations above screening criteria.

In general, many of the metals detected in site samples are typically persistent in the environment. This persistence is related primarily to recycling mechanisms (e.g., for arsenic, lead and copper), and removal mechanisms (e.g., precipitation, cationic exchange, adsorption,

etc.) that decrease mobility and, therefore, transport. Degradation does not occur for the majority of these materials due to their elemental (or ionized) state. High solubility of some metal-based salts facilitates their migration in surface or ground waters. Overall, however, elevated heavy metal contaminant contributions at the Pownal Tannery Superfund Site are primarily associated with lagoon sludge and river sediment.

Cyanide was also detected in site soil, lagoon sludge/soil and river sediment. Cyanide mobility in the environment is a function of solubility and pH of the water in which it may dissolve (EPRI, 1991). Cyanide forms a variety of complex species of variable stability; their dissociation is a function of pH. Complexes that break down under mildly acidic and cobalt cyanides require very acidic ($\text{pH} < 2$) conditions. As with most cyanides, the solubility increases with pH. A major dissolution effect results at pHs between 8 and 9; pH below 7 has little effect on solubility.

5.4 Transport Processes

Migration and persistence are controlled by various transport and attenuation processes. Processes that tend to disperse contaminants include surface water and ground water movement (which includes the movement of dissolved and suspended contaminants), facilitated transport, leaching by dissolution or desorption, and surface erosion.

5.4.1 Advection and Dispersion

Dissolved phase transport can occur via two processes: advection or dispersion. Advection involves transport with flowing ground water and migrating with the mean velocity of the solvent (ground water plus dissolved compounds). Ignoring attenuating mechanisms, dissolved constituents will flow with ground water in the direction of decreasing hydraulic head at an average rate equal to the ground water seepage velocity.

When compounds move through the ground by advection, they are subject to spreading within the ground, which allows compounds with little or no affinity for soils to migrate faster than the mean ground water velocity. This spreading is the result of a process known as dispersion. Hydrodynamic dispersion has two components: molecular diffusion and mechanical dispersion (USEPA, 1989a). Diffusion is the process by which ionic or molecular constituents move under the influence of concentration gradients. Mechanical dispersion occurs as the ground water flows through the media, and compounds spread out through the tortuous pathways of the soil matrix, and mix with clean water. The result is a dilution of the compound by a process known as dispersion (Fetter, 1988). At very low ground water velocities, diffusion is the dominant process; at higher velocities, mechanical dispersion is the dominant process. Dispersivity is dependant on vertical and horizontal permeability variations, increasing with the degree of heterogeneity and anisotropy, and is dependant on whether flow is principally through porous media or nonporous media (e.g., fractured bedrock) (Walton, 1988). Mechanical dispersion is governed by soil characteristics represented by dispersion coefficients which are difficult to measure and may not ever be totally described for the complete hydrogeologic setting at the site. Contaminant migration via dispersion is believed to be less important than advective transport.

5.4.2 *Facilitated Transport*

The rate a compound migrates can be influenced by facilitated transport, which is the combined effects of physical, chemical, and/or biological phenomena that act to increase mobility. Examples of facilitated transport include particle transport, cosolvation, and phase shifting (Keely, 1989).

Particle Transport: The movement of small, solid-phase particles (such as inorganic and organic colloids) macromolecules, or emulsions to which compounds have adhered by sorption, ion exchange, or other means. High molecular weight organic compounds such as polynuclear aromatic hydrocarbons (PAHs), pesticides, PCBs, and heavy metals have a high affinity for mobile subsurface particles, and this affinity increases their mobility (Huling, 1989). Small particles, especially mobile organic carbon phase particles such as biocolloids and macromolecules (e.g., humic substances) are transported in the aqueous phase and may act as mobile sorbents.

Cosolvation: The process by which the solubility and mobility of one compound is increased by the presence of another (Keely, 1989). Naturally occurring organic compounds (e.g., humic acids) can undergo complexation reactions with metals and pesticides. Complexation reactions can increase the solubility of metals (including iron, aluminum, copper, nickel and lead) and pesticides (e.g., dichlorodiphenyl trichloroethane [DDT]). In a cosolvent system, as the fraction of a water-miscible cosolvent increases, the solubility of the metals or pesticides increase. However, the cosolvent concentration normally needs to be high to ensure a substantial increase in solute velocity. Therefore, cosolvation is important primarily near sources of ground water impact (USEPA, 1989a). However, high concentrations of water-miscible phases (e.g., ketones) were not detected at the Pownal Tannery Superfund Site.

5.5 **Attenuation Processes**

Processes that tend to attenuate migration of impacted ground water include retardation resulting from sorption, volatilization, degradation, and precipitation.

Adsorption: Adsorption is perhaps the most significant attenuation mechanism for contaminants migrating through saturated soils. Primary adsorption sites include organic matter, which is present at variable levels within essentially all soils, and colloidal particles. The sorption properties of individual solutes are dependant on soil and ground water characteristics. In general, the relative amount of sorption by soil or sediment materials that do not contain organic matter is as follows: clay > silt > sand > gravel (Walton, 1988).

The soil at the site includes a substantial clay stratum that underlies the majority of the site. Sorption would be expected to exert a moderate to strong influence in retarding the migration of non-chlorinated VOCs and SVOCs in the soil and a strong influence on retarding PCB migration in soil. For organic compounds adsorption typically increases with molecular weight within homologous series. In other words, lower molecular weight compounds, such as certain volatiles, generally display increased mobility in comparison to heavier extractable organics. For some polar organic and inorganic compounds, adsorption can entail the formation of relatively

strong bonds with substrates normally found in natural soils such as clay minerals or humic substances.

With respect to transport of organic compounds, adsorption tends to be reversible and acts to impede or retard the advective solute front and, is important in consideration of potential contaminant transport times. The degree of impedance or retardation is defined as the Retardation Factor, R (Freeze & Cherry, 1979):

$$R = \frac{V}{V_t}$$

where V = ground water seepage velocity
 V_t = ground water transport velocity

Studies have shown that for some organic compounds the retardation factor can be estimated by the following relationship (Freeze & Cherry, 1979):

$$R = 1 + \frac{Pb \cdot K_d}{n}$$

where Pb = bulk dry soil density
 K_d = distribution coefficient
 n = soil porosity

The distribution coefficient (K_d) is defined as the mass of solute on the solid phase per unit mass of solid phase, per concentration of solute in solution (Freeze & Cherry, 1979) (see Section 5.2). Consequently, the larger the distribution coefficient the less mobile the solute. For many organic compounds, K_d can be estimated by:

$$K_d = f_{oc} \cdot K_{oc}$$

where f_{oc} = fraction of organic carbon in the soil matrix
 K_{oc} = organic carbon partition coefficient.

The bulk dry soil density, soil porosity, and fraction of organic carbon are all properties of the soil itself. However, the organic carbon partition coefficient (K_{oc}) is a function of the individual compound, and consequently may vary considerably among compounds, resulting in a range of retardation factors for compounds observed at the site. When more than one compound is migrating in ground water, contaminant plume segregation and variable arrival times are often the result.

Adsorption may also retard the migration of metals; however, the distribution coefficient, and consequently the retardation factor, is partially a function of the cation exchange capacity of the soil media, the ionization state of the metal contaminant, and pH of the ground water. Metals tend to be more soluble and more mobile in ground water with a low pH. For many metals,

adsorption, and thus retardation factors, may be very high at pH values greater than 8 or 9. For some metals, notably zinc, copper, and cadmium, adsorption may be almost complete in ground water with a pH above 8 (Palmer et al., 1987).

Biodegradation: Biological transformation of organic compounds by microorganism in the soil column can be a potentially significant mechanism of attenuation. The rates and byproducts of biodegradation can be highly variable depending upon the nature of the contaminants present, the species of microorganisms, availability of nutrients, and general ground water chemistry. Certain aromatic compounds have been known to be susceptible to biological degradation; recent research has demonstrated that many halogenated aliphatic compounds are also biologically transformed under certain conditions.

Volatilization: Volatilization can result in substantial reductions of concentrations may result in the degradation of VOCs as ground water discharges to surface water environments.

Precipitation: Chemical phase shifts caused by changes in pH and/or the oxidation/reduction potential of the ground water can increase solubilities and mobilities by ionizing neutral organics, solubilizing precipitated metals, forming complexes, or limiting biological activity (Keely, 1989). These processes are particularly important in determining the mobility of heavy metals. Inorganics and heavy metals are chemical contaminants at the Pownal Superfund Site.

5.6 Contaminant Sources and Migration Pathways

There are several areas where the data indicate past releases of chemical into the environment. A discussion of each source area is presented below.

5.6.1 Landfill

Landfill cells: The contents of the landfill are a potential source of ground water contamination, but ground water in the Landfill Area does not appear to be impacted. The landfill is now capped, so direct exposure and infiltration should be minimized or eliminated.

Leachate tank: There are reports that the leachate collection tank regularly filled and was not drained regularly by the Pownal Tanning Company, during operation of the facility. Overflow of leachate into the ground is a potential source of ground water contamination, but no impacts were noted in the landfill area ground water.

5.6.2 Former Tannery Building Area

UST, piping: One underground storage tank was removed by the USACE, and the tank was observed to have several holes. Anecdotal reports from former tannery workers indicated that this tank may have been used to store solvents. Leakage from this tank into soil and bedrock appears to have occurred.

Building: The USACE reported PCP contamination of the interior building surfaces prior to demolition of the former tannery. It is possible that these compounds could have been released

to the soil from the tannery building.

Soils: A large volume of soil within the former tannery footprint was removed by the USACE as part of the NTCRA. The soils were contaminated with metals, and could be a source of metal contaminant releases.

5.6.3 Lagoon Area

Lagoon Sludge: The sludge in the lagoons is probably the most obvious potential contaminant source at the site since the lagoons are not covered, and they lie adjacent to the Hoosic River. Laboratory testing indicated high concentrations of metals, dioxins and organic compounds in the sludge of the Lagoon Area.

Former buildings: The USACE reported that oil staining was observed after the on-site structures in the Lagoon Area were demolished. The former above ground tanks located adjacent to the clarifier building did not have bottoms, so it is possible that these could be sourced of contaminant releases.

Sewage outfall: The sewage outfall to the Hoosic River is an obvious potential source of not only chemical contamination, but also biological contamination.

5.6.4 Warehouse Area

Floor Drains: The floor drains and scale pits in the warehouse contained contaminated soil that was removed by the USACE during the NTCRA. It is possible that releases might have occurred from these areas if the warehouse floor is cracked.

Hide Storage Areas: Reported hide storage areas were located on the unpaved areas east of the warehouse. Contaminants might have been released from this area during handling of tanned hides.

5.6.5 Woods Road Waste Disposal Area

Debris Mass: The fill encountered in the Woods Road Waste Disposal Area contained metals, leather, oil, and demolition debris that could be a contaminant source.

5.7 Migration Pathways

Chemical constituents have the potential to move through a variety of environmental media. At the Pownal Tannery Superfund Site, compounds of interest are present in surface soils, subsurface soils, sediments, surface water and ground water. In addition, low concentrations of several compounds were detected in air samples collected from certain subsurface exploration locations. At the site, offsite migration of site contaminants is expected to be possible via several mechanisms. A discussion of the contaminant migration pathways is provided below.

5.7.1 Wind

Compounds of concern may be transported as vapor (for the volatile constituents), or as an adsorbed component of released particulates. Relatively low concentrations of compounds of concern were detected in surface soils. Consequently, it appears that minimal transport of site contaminants will occur by this route.

5.7.2 Soil Erosion

Surface erosion can occur anywhere there is unpaved soil (e.g., the warehouse hide storage area, the lagoons, the Woods Road Waste Disposal Area, the Landfill prior to capping). Mobilized surface soils may carry adsorbed contaminants by wind or surface water transport, or release soluble constituents to surface or ground water media.

5.7.3 Surface Water Transport

Surface waters associated with the Pownal Tannery Superfund Site are associated with the adjacent Hoosic River, lagoon ponds and landfill streams and seeps. Ultimately, all site surface water is directed to the Hoosic River. Persistent contaminants (i.e. non-VOCs) that are released to surface water will be transported via stream flow in the streams and river.

5.7.4 Sediment Transport

Contaminated sediment may be transported as bedload or as suspended particles, and the rate of flow will vary depending upon the stage of the river. The results of sediment sampling indicate that the Hoosic River sediment is fine grained and contains site contaminants. Therefore, it is possible that site contamination brought into the Hoosic River will be transported downstream.

5.7.5 Leaching to Ground Water

There are generally two aquifers at the site, one unconfined overburden aquifer and one confined bedrock aquifer. The aquifers are separated by a thick confining clay layer. Overburden ground water flow at the Lagoon area is radially to the west, toward the Hoosic River. There are very strong vertical hydraulic gradients in the Lagoon and Landfill areas, directed upward, indicating that the bedrock aquifer is confined. Except for one well located in the center of the Lagoon area (MW-109), all of the ground water tested on the site contains site contaminants at concentrations below the Federal Maximum Contaminant Levels (MCL). Monitoring well MW-109U contained thallium at a concentration that exceeds the MCL. While it is certainly possible for site contaminants to be leached into ground water, this does not appear to be an active transport mechanism at the site.

5.8 Receptors

Identification of potentially exposed human receptors depends somewhat on the future use of the property following remediation. These could include future residents or workers on the site, construction workers, and recreational users of the site and environs. Current receptors include

trespassers, outdoor workers, recreational users of the Hoosic River, and any users of the ground water.

Potentially exposed ecological receptors include both aquatic and terrestrial types. Potential aquatic receptors include benthic invertebrates in wetland and stream areas, fish in the river, wetland plants, wetland invertebrates, amphibians and reptiles, and birds and mammals that forage within wetlands and/or the river. Potential terrestrial receptors include upland vegetation, soil invertebrates, songbirds and carnivorous omnivorous and herbivorous mammals and birds that forage within the terrestrial cover types. Previous investigations have observed dead animals such as mice and raccoons onsite, and previous wildlife observations have confirmed the potential presence of these types of species.

Table 5.2-1: Detected Volatile Organic Compounds (VOCs)	
Halogenated VOCs	Non-Halogenated VOCs
1,1,1-Trichloroethane	2-Butanone
1,1,2,2-Tetrachloroethane	2-Hexanone
1,1,2-Trichloro-1,2,2-Trifluoroethane	4-Methyl-2-pentanone
1,1,2-Trichloroethane	Acetone
1,1-Dichloroethane	Benzene
1,1-Dichloroethene	Carbon disulfide
1,2,4-Trichlorobenzene	Cyclohexane
1,2-Dibromo-3-chloropropane	Ethylbenzene
1,2-Dibromoethane	Isopropylbenzene
1,2-Dichlorobenzene	Methyl Acetate
1,2-Dichloroethane	Methyl tert-butyl ether
1,2-Dichloropropane	Methylcyclohexane
1,3-Dichlorobenzene	Styrene
1,4-Dichlorobenzene	Toluene
Bromodichloromethane	Xylene (total)
Bromoform	1,2-Dimethyl-4-ethylbenzene
Bromomethane	
Carbon tetrachloride	
Chlorobenzene	
Chloroform	
Chloromethane	
Cis-1,2-Dichloroethylene	
Cis-1,3-Dichloropropene	
Dibromochloromethane	
Dichlorodifluoromethane	
Methylene chloride	
Tetrachloroethylene	
Trans-1,3-Dichloropropene	
Trichloroethylene	
Trichlorofluoromethane	
Vinyl chloride	

Table 5.2-2: Detected Semivolatile Organic Compounds			
Acid Extractables	PAHs	Base-Neutral Extractables	Phthalate Esters
2,4,5-Trichlorophenol	2-Methylnaphthalene	2-Nitroaniline	Bis(2-ethylhexyl)phthalate(DEHP)
2,4,6-Trichlorophenol	Acenaphthene	4-Chloroaniline	Diethyl phthalate
2,4-Dichlorophenol	Acenaphthylene	Benzaldehyde	Di-n-butyl phthalate
2,4-Dimethylphenol	Anthracene	Biphenyl	Butylbenzylphthalate
2-Methylphenol	Benzo(a)anthracene	Bis(2-chloro-1-methylethyl)ether	Di-n-octylphthalate
2-Nitrophenol	Benzo(a)pyrene	Bis(2-chloroethyl)ether	
4-Chloro-3-methylphenol	Benzo(b)fluoranthene	Caprolactam	
4-Methylphenol	Benzo(g,h,i)perylene	Nitrobenzene	
4-Nitrophenol	Benzo(k)fluoranthene	N-Nitrosodi-n-propylamine	
Pentachlorophenol	Carbazole	Bis(2-chlordethoxymethane	
Phenol	Chrysene		
	Dibenzo(a,h)anthracene		
	Dibenzofuran		
	Fluoranthene		
	Fluorene		
	Indeno(1,2,3-cd)pyrene		
	Naphthalene		
	Phenanthrene		
	Pyrene		
	Isophopone		

Table 5.2-3: Detected Inorganics (Metals/Cyanide)	
Aluminum	Magnesium
Antimony	Manganese
Arsenic	Mercury
Barium	Nickel
Beryllium	Potassium
Cadmium	Selenium
Calcium	Silver
Chromium	Sodium
Cobalt	Thallium
Copper	Vanadium
Iron	Zinc
Lead	Cyanide

Table 5.2-4: Detected Pesticides/PCBs	
Pesticides	PCBs
4,4'-DDD	Aroclor 1242
4,4'-DDE	Aroclor 1248
4,4'-DDT	Aroclor 1254
Aldrin	Aroclor 1260
Alpha-BHC	
Alpha-Chlordane	
Beta-BHC	
Delta-BHC	
Dieldrin	
Endosulfan I	
Endosulfan II	
Endosulfan sulfate	
Endrin	
Endrin aldehyde	
Endrin ketone	
Gamma-chlordane	
Heptachlor	
Heptachlor epoxide	
Gamma-BHC (lindane)	
Methoxychlor	

Table 5.2-5: Detected Dioxin/Furan Isomers	
Dioxins	Furans
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	1,2,3,7,8,9-Hexachlorodibenzofuran
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	1,2,3,4,6,7,8-Heptachlorodibenzofuran
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	1,2,3,4,7,8,9-Heptachlorodibenzofuran
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	1,2,3,4,7,8-Hexachlorodibenzofuran
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	1,2,3,6,7,8-Hexachlorodibenzofuran
2,3,7,8-Tetrachlorodibenzo-p-dioxin	1,2,3,7,8-Pentachlorodibenzofuran
Heptachlorodibenzo-p-dioxins (total)	2,3,4,6,7,8-Hexachlorodibenzofuran
Hexachlorodibenzo-p-dioxins (total)	2,3,4,7,8-Pentachlorodibenzofuran
Octachlorodibenzo-p-dioxin	2,3,7,8-Tetrachlorodibenzofuran
Octachlorodibenzo-p-dioxins (total)	Heptachlorodibenzofurans (total)
Pentachlorodibenzo-p-dioxins (total)	Hexachlorodibenzofurans (total)
Tetrachlorodibenzo-p-dioxins (total)	Octachlorodibenzofuran
	Octachlorodibenzofurans (total)
	Pentachlorodibenzofurans (total)
	Tetrachlorodibenzofurans (total)
	Trichlorodibenzofurans (total)

Table 5.2-6: Physical/Chemical Properties – Volatile Organic Compounds							
Chemical	Molecular Weight (grams/mole)	Aqueous Solubility (mg/L)	Vapor Pressure mmHg (at 68°F unless noted)	Henry's Law Constant (atm-m ³ /mol unless noted)	Partition Coefficients		Specific Gravity (at 68° F unless noted)
					K _{ow}	K _{oc} ml/g	
Halogenated VOCs							
1,1,1-Trichloroethane	133.41 ¹	1,500 ⁶	100 ²	1.44x10 ⁻² (6)	316 ⁶	152 ⁶	1.34 ²
1,1,2,2-Tetrachloroethane	165.83 ³	2,900 ⁶	14 ³	3.81x10 ⁻⁴ (6)	245 ⁶	118 ⁶	1.626 ³
1,1,2-Trichloro-1,2,2-Trifluoroethane (Freon-113)	187.37 ⁴	10 ⁶	285 ²	0.245 ⁹	100 ⁶	390 ⁹	1.5702 ⁴
1,1,2-Trichloroethane	133.4 ²	4,500 ⁶	19 ²	1.17x10 ⁻³ (6)	295 ⁶	56 ⁶	1.44 ²
1,1-Dichloroethane	99.0 ²	5,500 ⁶	182 ²	4.3x10 ⁻³ (6)	61.7 ⁶	30 ⁶	1.18 ²
1,1-Dichloroethene	96.9 ²	2,250 ⁶	500 ²	3.4x10 ⁻² (6)	69.2 ⁶	65 ⁶	1.21 ²
1,2,4-Trichlorobenzene	181.4 ²	30 ⁶	1 ²	2.31x10 ⁻³ (6)	20,000 ⁶	9,200 ⁶	1.45 ²
1,2-Dibromo-3-chloropropane	236.35 ⁴	1270 ⁹	0.8 ²	2.49x10 ⁻⁴ 9	320 ⁹	130 ⁹	2.05 ²
1,2-Dibromoethane	187.9 ²	4321 ⁹	12 ²	5.21x10 ⁻⁴ 9	85 ⁹	44 ⁹	2.17 ²
1,2-Dichlorobenzene (a.d. chlorobenzene)	147.0 ²	100 ⁶	1 ²	1.93x10 ⁻³ (6)	3,980 ⁶	1,700 ⁶	1.30 ²
1,2-Dichloroethane	99.0 ²	8,520 ⁶	64 ²	9.78x10 ⁻³ (6)	30.2 ⁶	14 ⁶	1.24 ²
1,2-Dichloropropane	113.0 ²	2,700 ⁹	40 ²	2.19x10 ⁻³	100 ⁹	47 ⁹	1.16 ²
1,3-Dichlorobenzene (m-dichlorobenzene)	147.01 ³	123 ³ at 25°C	2.28 ⁶	3.59x10 ⁻³ (6)	3,980 ⁶	1,700 ⁶	1.288 ³
1,4-Dichlorobenzene (p-dichlorobenzene)	147 ²	79 ⁶	1.3 ²	2.89x10 ⁻³ (6)	3,980 ⁶	1,700 ⁶	1.25 ²
Bromodichloromethane	163.8 ³	4,400 ⁶	50 ⁶	2.4x10 ⁻³ (6)	75.9 ⁶	61 ⁶	1.971 ³
Bromoform	252.8 ²	3,010 ⁶	5 ²	5.52x10 ⁻⁴ (6)	251 ⁶	116 ⁶	2.89 ²
Bromomethane (methylbromide)	114.2 ²	13,000 ⁶	1,400 ⁶	1.3x10 ⁻² (6)	12.6 ⁶		0.81 ²
Carbon tetrachloride	153.8 ²	757 ⁶	91 ²	2.41x10 ⁻² (6)	437 ⁶	439 ⁶	1.59 ²
Chlorobenzene	112.6 ²	466 ⁶	9 ²	3.72x10 ⁻³ (6)	692 ⁶	330 ⁶	1.11 ²
Chloroethane (vinyl chloride)	62.5 ²	2,670 ⁶	3.3 ²	8.19x10 ⁻² (6)	24 ⁶	57 ⁶	0.9121 at 15°C ³
Chloroform	119.4 ²	8,200 ⁶	160 ²	2.873x10 ⁻³ (6)	93.3 ⁶	47 ⁶	1.48 ²
Chloromethane	50.4 ²	6,500 ⁶	4,310 ⁶	4.40x10 ⁻² (6)	0.95 ⁶	35 ⁶	0.991 at – 25°C ³
Cis-1,2-Dichloroethylene	96.94 ⁵	3,500 ⁶	208 ⁶	7.58x10 ⁻³ (6)	5.01 ⁶	49 ⁶	
Cis-1,3-Dichloropropene	110.97 ⁴	1,990 ⁵	26.7 at 25°C ⁵	2.71x10 ⁻³ (6)	25.7 ⁹	23 ⁹	1.22 ⁹
Dibromochloromethane	208.29 ⁴	2,700 ⁵	5.7 ²	7.83 x10 ⁻⁴ (5)	120 ⁹	83 ⁹	2.44 at 25°C/25°C ⁴
Dichlorodifluoromethane (Freon-12)	120.9 ²	280 ⁶	4,250 ³	2.97 (6)	145 ⁶	58 ⁶	1.329 at 20°C
Methylene chloride	84.9 ²	20,000 ⁶	350 ²	2.03 x10 ⁻³ (6)	20 ⁶	8.8 ⁶	1.33 ²
Tetrachloroethylene	165.8 ²	150 ⁶	14 ²	2.59 x10 ⁻² (6)	398 ⁶	364 ⁶	1.62 ²

Table 5.2-6: Physical/Chemical Properties – Volatile Organic Compounds							
Chemical	Molecular Weight (grams/mole)	Aqueous Solubility (mg/L)	Vapor Pressure mmHg (at 68°F unless noted)	Henry's Law Constant (atm-m ³ /mol unless noted)	Partition Coefficients		Specific Gravity (at 68° F unless noted)
					K _{ow}	K _{oc} ml/g	
Trans-1,3-Dichloropropene	110.97 ⁴	1,990 ⁵	26.7 ⁵	8.71 x10 ⁻⁴ (6)	107 ⁵		
Trichloroethylene	131.4 ²	1,100 ⁶	58 ²	9.1 x10 ⁻³ (6)	240 ⁶	126 ⁶	1.46 ²
Trichlorofluoromethane (Freon-11)	137.4 ²	1,100 ⁶	690 ²	1.1 x10 ⁻¹ (6)	339 ⁶	159 ⁶	1.47 at 75°F ²
Vinyl chloride	62.5 ²	2,670 ⁶	3.3 ²	8.19 x10 ⁻² (6)	24 ⁶	57 ⁶	0.9121 at 15°C ³
Non-Halogenated VOCs							
2-Butanone	72.1 ²	268,000 ⁶	78 ²	2.74 x10 ⁻⁵ (6)	4.5 ⁶	1.82 ⁶	0.81 ²
2-Hexanone	100.2 ²	14,000 ⁶	11 ²	2.82 x10 ⁻⁵ (6)	15.5 ⁹	135 ⁹	0.81 ²
4-Methyl-2-pentanone	100.2 ²	17,000 ⁶	16 ²	1.55 x10 ⁻⁴ (6)	20.4 ⁹	6.17 ⁹	0.80 ²
1,2-Dimethyl-4- ethylbenzene	134.22 ⁵	12.7 (5)	9.61x10 ⁻³ (5)	31,600 ⁵			
Acetone	58.1 ²	Infinite ⁶	180 ²	2.06 x10 ⁻⁵ (6)	0.575 ₆	2.2 ⁶	0.79 ²
Benzene	78.1 ²	1,750 ⁶	75 ²	5.59 x10 ⁻³ (6)	132 ⁶	83 ⁶	0.88 ²
Carbon disulfide	76.1 ²	2,940 ⁶	297 ²	1.23 x10 ⁻² (6)	100 ⁶	54 ⁶	1.26 ²
Cyclohexane	82.2 ²	110 ⁹	67 ²	1.4x10 ⁻¹ 9	2,750 ⁹		0.81 ²
Ethylbenzene	106.2 ²	152 ⁶	7 ²	6.43 x10 ⁻³ (6)	1,410 ⁶	1,100	0.87 ²
Isopropylbenzene (cumene)	120.2 ²	48.3 ⁹	8 ²	5.03x10 ⁻³ 9	3,230 ⁹	2,500 ⁹	0.86 ²
Methyl Acetate	74.1 ³	245,000 ⁹	170 ³	1.28x10 ⁻⁴ (9)	1.5 ⁹		0.93 at 25°C ³
Methyl tert-butyl ether	88.15 ⁵	51,000 ⁵	249 ⁵	5.87 x10 ⁻⁴ (6)	8.7 ⁵		
Methylcyclohexane	98.18 ³	14 at 20°C ³	144 ³	6.78 x10 ⁻² (25°C) 9	600 ⁹		0.77 at 20°C/4°C ³
Styrene	104.2 ²	300 ⁶	5 ²	2.05 x10 ⁻³ (6)	575 ⁹	912 ⁹	0.91 ²
Tetrahydrofuran	72.11 ⁵	1,000,000 ⁵	162 ⁵	7.0 x10 ⁻⁵	2.88 ⁵	23.4 ⁹	0.8892 ⁹
Toluene	92.1 ²	535 ⁶	21 ²	6.37 x10 ⁻³ (6)	537 ⁶	300 ⁶	0.87 ²
Xylene (total)	106.2 ²	198 ⁶	7 to 9 ²	7.04 x10 ⁻³ (6)	1,830 ⁶	240 ⁶	0.86 to 0.88 ²

Table 5.2-7: Physical/Chemical Properties - Semivolatile Organic Compounds

Chemical	Molecular Weight (grams/mole)	Aqueous Solubility (mg/L)	Vapor Pressure mmHg (at 68°F unless noted)	Henry's Law Constant (atm-m ³ /mol unless noted)	Partition Coefficients		Specific Gravity	Bioconcentration Factor (K _B)
					K _{ow}	K _{oc} ml/g		
Acid Extractable								
2,4,5-Trichlorophenol	197 ⁷	1,190 ⁷	1.0 ⁶	2.18x10 ⁻⁴ 7	5,250 ⁷	89 ⁷	1.5 (75°F) ⁹	1,905 ⁽¹²⁾
2,4,6-Trichlorophenol	197 ⁷	800 ⁷	0.012 ⁶	4.0x10 ⁻⁶ 7	7,410 ⁶	2,000 ⁶	1.49 (75°F) ⁹	154,375 ⁽¹²⁾
2,4-Dichlorophenol	163 ⁷	4,500 ⁷	0.059 ⁶	2.8x10 ⁻⁶ 7	831 ⁷	380 ⁶	1.4 (15°C) ⁹	17,312 ⁽¹²⁾
2,4-Dimethylphenol	122 ⁷	7,870 ⁷	6.21x10 ⁻² 9	1.7x10 ⁻⁵ 7	200 ⁷	40 ⁷	0.96 ⁹	4,167 ¹²
2-Methylphenol (o-cresol)	108.14 ⁸	2,500 ⁶	0.243 ⁶	1.5x10 ⁻⁶ 6	89.1 ⁶	50 ⁹ river sediment	1.05 ²	1,856 ¹²
2-Nitrophenol	139.11 ⁸	2,100 ⁶	0.087 (9)	3.5x10 ⁻⁶ 9	57.5 ⁶	61.7 ⁹ river sediment	1.495 ⁹	1,198 ¹²
4-Chloro-3-methylphenol	142.58 ⁸	3,850 ⁶	0.050 ⁶	2.44x10 ⁻⁶ (6)	980 ⁶	490 ⁶		20,417 ¹²
4-Methylphenol (p-cresol)	108.14 ⁸	18,000 (9)	0.114 ⁶	7.69x10 ⁻⁷ (9)	85.1 ⁶	500 ⁹	1.04 ²	1,773 ¹²
4-Nitrophenol (pNitrophenol)	139.11 ⁸	16,000 ⁶	10x10 ⁻⁵ 9	3.85x10 ⁻¹⁰ (9)	81.3 ⁶	234 ⁹	1.479 ⁹	30.2 activated sludge ⁹
Pentachlorophenol	266 ⁷	14 ⁷	0.0001 (77°F)	2.8x10 ⁻⁶ 7	102,330 ⁷	32,000 ⁷	1.98 ²	2,130,000 ¹²
Phenol	94 ⁷	80,000 ⁷	0.4 ²	1.3x10 ⁻⁶ 7	28.8 ⁷	91 ⁷	1.06 ²	600 ¹²
PAHs								
2-Methylnaphthalene	142 ⁷	26 ⁷	0.051 (9)	2.9x10 ⁻⁴ 7	7,244 ⁷	720 ⁷	1.0058 ⁹	6170 ⁹
Acenaphthene	154 ⁷	3.42 ⁷	0.00155 ⁶	9.20.10 ⁻⁵ (6)	9,550 ⁷	4,600 ⁷	1.0242 (90°C/4°C) ⁹	380 bluegill sunfish ⁽⁹⁾
Acenaphthylene	152.19 ⁸	3.93 ⁷	0.0290 ⁶	1.45x10 ⁻³ 7	5,010 ⁶	2,500 ⁷	0.8988 (16°C) ⁹	380 ⁹
Anthracene	178 ⁷	0.045 ⁶	1.95x10 ⁻⁴ (6)	10.20x10 ⁻³ (6)	28,200 ⁶	14,000 ⁷	1.24 ⁹	6,760 activated sludge ⁽⁹⁾
Benzo(a)anthracene	228 ⁷	0.057 ⁶	2.20x10 ⁻⁶ (6)	1.16x10 ⁻⁶ (6)	398,000 ⁶	200,000 ⁶	1.274 ⁹	10,000 Daphnia pulex ⁽⁹⁾
Benzo(a)pyrene	252 ⁷	0.012 ⁶	560x10 ⁻⁹ (6)	1.55x10 ⁻⁶ (6)	1,1150,00 0 ⁶	5,500,000 6	1.351 ⁹	4,900 Bluegill sunfish ⁽⁹⁾
Benzo(b)fluoranthene	252 ⁷	0.014 ⁷	5.0x10 ⁻⁷ (6)	1.22x10 ⁻⁵ 7	1,150,000 6	550,000 ⁷		10,000 Daphnia magna ⁽⁹⁾
Benzo(g,h,i)perylene	279 ⁷	0.0007 ⁶	1.03x10 ⁻¹⁰ (6)	5.34x10 ⁻⁸ (6)	3,240,000 6	1,600,000 7		2,820C Daphnia magna ⁽⁹⁾
Benzo(k)fluoranthene	252 ⁷	0.0043 ⁶	5.10x10 ⁻⁷ (6)	3.87x10 ⁻⁵ 7	1,150,000 6	550,000 ⁷		10,000 Daphnia magna ⁽⁹⁾
Carbazole	167.21 ⁸	1.8 (5)	1.1x10 ⁻⁴ (5)	1.0x10 ⁻⁴ (6)	15,100 ⁵			724.8 ¹²
Chrysene	228 ⁷	0.0018 ⁶	6.3x10 ⁻⁹ (6)	1.05x10 ⁻⁶ 7	407,000 ⁷	200,000 ⁷	1.274 ⁹	6,170 Daphnia magna ⁽⁹⁾
Dibenzo(a,h)anthracene	278 ⁷	0.0005 ⁷	1.0x10 ⁻¹⁰ (6)	7.3x10 ⁻⁸ 7	6,310,000 6	3,300,000 7	1.282 ⁹	10,000 Daphnia magna ⁽⁹⁾
Dibenzofuran	168.19 ⁸	10.03 (9)	2.63x10 ⁻³ (9)	5.82.10 ⁻⁵ (9)	20,420 ⁹	34,700 ⁽⁹⁾ claytill	1.0886 (99/4°C) ⁹	1,350 fathead minnow ⁽⁹⁾

Table 5.2-7: Physical/Chemical Properties - Semivolatile Organic Compounds

Chemical	Molecular Weight (grams/mole)	Aqueous Solubility (mg/L)	Vapor Pressure mmHg (at 68°F unless noted)	Henry's Law Constant (atm-m ³ /mol unless noted)	Partition Coefficients		Specific Gravity	Bioconcentration Factor (K _B)
					K _{ow}	K _{oc} ml/g		
Fluoranthene	202 ⁷	0.206 ⁶	50x10 ⁻⁶ (6)	6.5x10 ⁻⁶ 7	79,400 ⁷	38,000 ⁷	1.252 (0/4°C) ⁹	1,740 Daphnia magna ⁽⁹⁾
Fluorene	166 ⁷	1.69 ⁶	7.1x10 ⁻⁴ (6)	6.42x10 ⁻⁵ (6)	15,800 ⁶	7,300 ⁷	1.203 (0/4°C) ⁹	500 Daphnia magna ⁽⁹⁾
Indeno(1,2,3-cd)pyrene	276 ⁷	0.00053 ⁷	1x10 ⁻¹⁰ (6)	6.95x10 ⁻⁸ 7	3,801,894 ⁷	1,600,000 ⁷		
Naphthalene	128 ⁷	31.7 ⁶	2.3x10 ⁻¹ (6)	1.18x10 ⁻³ 7	2,760 ⁶	1,300 ⁶	1.145 ⁹	430 fish ⁽⁹⁾
Phenanthrene	178 ⁷	0.816 ⁷	6.8x10 ⁻⁴ (6)	1.59x10 ⁻⁴ (6)	28,184 ⁷	14,000 ⁷	1.179 (25/4°C) ⁹	930 Activated sludge ⁽⁹⁾
Pyrene	202 ⁷	0.16 ⁷	2.5x10 ⁻⁶	3.10x10 ⁻⁶ 7	75,858 ⁷	38,000 ⁷	1.271 (23/4°C) ⁹	2,700 Daphnia magna ⁽⁹⁾
Base Neutral Extractables								
2-Nitroaniline	138.12 ⁸	14,700 ⁶	8.1 (9)	9.72x10 ⁻⁵ (9)	61.7 ⁶	17-42 ⁹	1.44 ⁹	8.1 Brachydanio rerio ⁽⁹⁾
4-Chloroaniline	127.57 ⁸	3,900 ⁹	0.015 ⁹	1.07x10 ⁻⁵ (9)	105 ⁹	91.2 ⁹	1.429 ⁹	282 Activated sludge ⁽⁹⁾
Benzaldehyde	106.12 ⁸	3,000 (5)	0.127 (5)	2.67x10 ⁻⁵ (5)	30.2 ⁵			629 ¹²
Biphenyl	154.21 ⁸	7.48 (9)	251 (9)	3.08x10 ⁻⁴ (25°C)	10,000 ⁹	1,070 ⁹	0.8660 ⁹	340 fish ⁽⁹⁾
Bis(2-chloro-1-methylethyl)ether	171.06 ⁸	1,700 ⁹	0.56 ⁹	1.1x10 ⁻⁴ 9	300 ⁹	245 ⁹	1.103 ⁹	6,250 ¹²
Bis(2-chloroethyl)ether	143.01 ⁸	10,200 ⁶	0.71 ²	1.31x10 ⁻⁵ (6)	31.6 ⁶	13.9 ⁶	1.22 ²	858 ¹²
Caprolactam	113.16 ⁸	772,000 ⁵	0.0016 (5)	2.53x10 ⁻⁸ (5)	0.645 ⁵		1.01 ²	13.4 ¹²
Nitrobenzene	123.11 ⁸	1,900 ⁹	0.15 ⁹	2.5x10 ⁻⁵ (9)	70.1 ⁹	230 ⁹	1.20 ²	40 Activated sludge ⁽⁹⁾
N-Nitrosodi-n-propylamine	130.19 ⁸	9,900 (5)	0.13 (5)	5.38x10 ⁻⁶ (37°C)	20.4 ⁹	10.2 ⁹	0.916 ⁹	425 ¹²
Phthalate Esters								
Butylbenzyl phthalate	312.37 ⁹	42.2 ⁶	8.6x10 ⁻⁶ 9	1.3x10 ⁻⁶ (9)	63,100 ⁶	11,200 ⁹	1.12 ⁹	630 ⁹
Bis(2-ethylhexyl) phthalate(DEHP)	390.56 ⁸	0.285 ⁶	2.0x10 ⁻⁷ (6)	3.61x10 ⁻⁷ (6)	9,500 ⁶	5,900 ⁶	0.983 ⁹	3,020 Activated sludge ⁽⁹⁾
Diethyl phthalate	222.24 ⁸	896 ⁶	3.50x10 ⁻³ (6)	1.14x10 ⁻⁶ (6)	316 ⁶	142 ⁶	1.118 ⁹	120 Bluegill sunfish ⁽⁹⁾
Di-n-butyl phthalate	278.34 ⁸	13 ⁶	1.0x10 ⁻⁵ (6)	2.82x10 ⁻⁷ (6)	398,000 ⁶	170,000 ⁶	1.0465 (21/4°C) ⁹	1,400 fish ⁽⁹⁾

Table 5.2-8: Physical/Chemical Properties – Pesticides/PCBs

Chemical	Molecular Weight (grams/mole)	Aqueous Solubility (mg/L)	Vapor Pressure mmHg (at 68°F unless noted)	Henry's Law Constant (atm-m ³ /mol unless noted)	Partition Coefficients		Specific Gravity (at 68° F unless noted)	Bioconcentration Factor (K _B)
					K _{ow}	K _{oc} ml/g		
Detected Pesticides/PCBs								
4,4'-DDD	320.04 ⁸	0.10 ⁶	1.89x10 ⁻⁶ (6)	7.96x10 ⁻⁶ (6)	1,580,000 ₆	770,000 ⁶	1.476 ⁹	41,700 fish ⁽⁹⁾
4,4'-DDE	318.02 ⁸	0.04 ⁶	6.50x10 ⁻⁶ (6)	6.80x10 ⁻⁵ (6)	10,000,00 ₀ ⁶	4,400,000 ₆		12,000 fish ⁽⁹⁾
4,4'-DDT	354.48 ⁸	0.005 ⁶	5.50x10 ⁻⁶ (6)	5.13x10 ⁻⁴ (6)	1,550,000 ₆	243,000 ⁶	1.56 (15/4°C) ⁹	14,100 Activated sludge ⁽⁹⁾
Aldrin	365 ⁷	0.180 ⁶	6.00x10 ⁻⁶ (6)	1.60x10 ⁻⁵ (6)	200,000 ⁶	16,000 ⁶	1.70 ⁹	18,200 Activated sludge ⁽⁹⁾
Alpha-BHC	290.83 ⁹	1.63 ⁹	2.15x10 ⁻⁵ 9	5.3x10 ⁻⁶ 9	5,250 ⁹	1,995 ⁹	1.870 ⁹	617 Freshwater fish ⁽⁹⁾
Alpha-Chlordane	409.78 ⁹	0.051 ⁹	3.6x10 ⁻⁵ (9)	8.75x10 ⁻⁴ (23°C) ⁹	851,000 ⁹	58,900 ⁹		1,995 B. Subtilis ⁽⁹⁾
Aroclor 1248	288 ⁹	0.054 ⁶	4.9x10 ⁻⁴ (6)	3.50x10 ⁻³ (6)	562,000 ⁶	436,500 ⁹	1.41 (77°F) ⁹	70,800 Freshwater fish ⁽⁹⁾
Aroclor 1254	327 ⁹	0.012 ⁶	7.7x10 ⁻⁵ (6)	2.7x10 ⁻³ (6)	1,070,000 ₆	42,500 ⁶	1.38 (77°F) ⁹	2,190 Guppies ⁽⁹⁾
Beta-BHC	290.83 ⁹	5 ⁹	2.8x10 ⁻⁷ 9	2.3x10 ⁻⁷ 9	6,950 ⁹	3,160 ⁹	1.89 (66°F) ⁹	1,200 Activated sludge ⁽⁹⁾
Delta-BHC	290.83 ⁹	7 ⁹	1.7x10 ⁻⁵ 9	2.5x10 ⁻⁷ 9	13,800 ⁹	1,900 ⁹	1.87 ⁹	282 Oncorhynchus mykiss ⁽⁹⁾
Dieldrin	381 ⁷	0.195 ⁶	1.78x10 ⁻⁷ (6)	4.58x10 ⁻⁷ (6)	3,160 ⁶	1,700 ⁶	1.75 ⁹	17,800 Activated sludge ⁽⁹⁾
Endosulfan I	406.92 ⁸	0.51 ⁹	4.58x10 ⁻⁵ (9)	6.55x10 ⁻⁵ 9	3,550 ⁹	2,040 ⁹	1.745 ⁹	2,750 Whole body stripped mullet ⁽⁹⁾
Endosulfan II	406.93 ⁵	0.450 ⁵	1.0x10 ⁻⁵ (5)	1.31x10 ⁻⁵ (5)	8,510 ⁵	2,344 ⁹	1.745 ⁹	2,754 Striped mullet ⁽⁹⁾
Endosulfan sulfate	422.93 ⁵	0.16 ⁶	1.0x10 ⁻⁵ (5)	1.16x10 ⁻⁵ (5)	4,570 ⁶	2,344 ⁹		
Endrin	380.92 ⁹	0.024 ⁶	2.0x10 ⁻⁷ (6)	4.17x10 ⁻⁶ (6)	218,000 ⁶	7,762 ⁹ Beverly sandy loam	1.65 (9)	2,630 Freshwater fish ⁹
Endrin aldehyde	380.91 ⁵	.024 ⁵	2.0 x10 ⁻⁷ (5)	4.18 x10 ⁻⁶ (5)	63,096 ⁵	26,916 ⁹		
Endrin Ketone								
Gamma-Chlordane	409.78 ⁵	0.0014 3 (5)	2.52x10 ⁻⁵ (5)	7.03x10 ⁻⁵ (5)	21,900,00 0 ⁵			
Heptachlor	373.32 ⁵	0.180 ⁶	3.0x10 ⁻⁴ (6)	8.19x10 ⁻⁴ (6)	25,100 ⁶	0.00012 ⁶	1.66 ⁹	13,800 Freshwater fish ⁽⁹⁾
Heptachlor epoxide	389.32 ⁵	0.350 ⁶	3.0x10 ⁻⁴ (6)	4.39x10 ⁻⁴ (6)	501 ⁶	220 ⁶		14,450 Freshwater fish ⁽⁹⁾
Lindane (Gamma BHC)	290.83 ⁵	7.80 ⁶	1.6x10 ⁻⁴ (6)	7.85x10 ⁻⁶ (6)	7,940 ⁶	1,080 ⁶	1.5691 (23.6/4°C) ⁹	447 Freshwater fish ⁽⁹⁾
Methoxychlor	345.66 ⁵	0.0030 ⁵	2.58x10 ⁻⁶ (5)	1.58x10 ⁻⁵ (5)	47,500 ⁶	80,000 ⁶	1.41 (25/4°C) ⁹	8,320 Freshwater fish ⁽⁹⁾
Aroclor 1242	258 ²	0.20 ⁹	0.001 ²	2.8x10 ⁻⁴ 9	12,880 ⁹	4,790 to 56,200 ⁹	1.392 (15/4°C) ⁹	32,400 Fathead minnows ⁹
Aroclor 1260	370 ⁹	0.080 ⁹	63.1x10 ⁻⁷ 9	1.7x10 ⁻⁴ 9	8,130,000 ₉	2,630,000 ₉	1.58 ⁹	195,000 Fathead minnows ⁹

Table 5.2-9: Physical/Chemical Properties – Inorganics (metals/cyanide)								
Chemical	Molecular Weight (grams/mole)	Aqueous Solubility (mg/L)	Vapor Pressure mmHg (at 68°F unless noted)	Henry's Law Constant (atm-m ³ /mol unless noted)	Partition Coefficients		Specific Gravity (at 68° F unless noted)	Bioconcentration Factor (K _B)
					K _{ow}	K _{oc} ml/g		
Aluminum	26.98 ⁸	Insoluble ¹³					2.702 ¹³	
Antimony	122 ⁷	Insoluble ¹³	1.0 ⁶				6.684 ¹³	40 Freshwater fish ¹¹
Arsenic	75 ⁷	Insoluble ¹³	0 ⁶				5.72 ¹¹	333 Freshwater fish ¹¹
Barium	137.33 ⁸	Decomposes ¹³	0 ¹³				3.51 ¹³	
Beryllium	9.01 ⁸	Insoluble ¹³	0 ⁶				1.85 ¹¹	100 Fish ¹¹
Cadmium	112 ⁷	Insoluble ¹³	0 ⁶				8.642 ¹¹	3,000 Fish ¹¹
Calcium	40.08 ⁸	Decomposes to H ₂ + Ca(OH) ₂ ¹³	0 ¹³				1.54 ¹³	
Chromium	52.00 ⁸	Insoluble ¹³					7.20 ¹¹	200 Freshwater fish ¹¹
Cobalt	58.93 ⁸	Insoluble ¹³	0 ¹³				8.9 ¹³	
Copper	63.55 ⁸	Insoluble ¹³	0 ⁶				8.92 ¹³	200 Freshwater fish ¹¹
Cyanide	27 ⁷	1,000,000 ⁷		1.90x10 ⁻⁷	4.57 ⁷	9.2 ⁷		
Iron	55.85 ⁸	Insoluble ¹³	0 ¹³				7.86 ¹³	
Lead	207 ⁷	Insoluble ¹³	0 ⁶				11.3 ¹³	60 Fish ¹¹
Magnesium	24.31 ⁸	Insoluble ¹³	0 ¹³				1.74 ¹³	
Manganese	54.94 ⁸	Decomposes ¹³	0 ¹³				7.20 ¹³	
Mercury	201 ⁷	0.0192 (5°C) ¹¹	2.0x10 ⁻³ (6)	1.10x10 ⁻² (6)			13.546 ¹¹	1,000 Freshwater fish ¹¹
Nickel	59 ⁷	Insoluble ¹³	0 ⁶				8.9 ¹³	40 Freshwater fish ¹¹
Potassium	39.10 ⁸	Decomposes to KOH ¹³	0 ¹³				0.83 ¹³	
Selenium	79 ⁷	Insoluble ¹³	0 ⁶				450 ¹³	400 Fish ¹¹
Silver	108 ⁷	Insoluble ¹³	0 ⁶				10.5 ¹³	3,080 Freshwater fish ¹¹
Sodium	22.99 ⁸	Decomposes to NaOH + H ₂ ¹³	0 ¹³				0.97 ¹³	
Thallium	204 ⁷	Insoluble ¹³	0 ⁶				11.85 ¹³	100,000 Freshwater fish ¹¹
Vanadium	50.94 ⁸	Insoluble ¹³					5.96 ¹³	
Zinc	65 ⁷	Insoluble ¹³	0 ⁶				7.14 ¹³	1,000 Freshwater fish ¹¹

Table 5.2-10: Physical/Chemical Properties – Dioxins/Dibenzofurans

Chemical	Molecular Weight (grams/mole)	Aqueous Solubility (mg/L)	Vapor Pressure mmHg (at 68°F unless noted)	Henry's Law Constant (atm·m ³ /mol unless noted)	Partition Coefficients		Specific Gravity (at 68° F unless noted)	Bioconcentration Factor (K _B)
					K _{ow}	K _{oc} ml/g		
Dioxins								
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	390.87 ⁵	4.4x10 ⁻⁶ (5)	9.47x10 ⁻⁸ (5)	1.94x10 ⁻⁶ (5)	63,000,000 ⁵	12,600,000 ¹⁰	2.52 ^{10*}	4,265 Fathead minnows (10)
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	390.87 ⁵	2.65x10 ⁻⁵ (5)	9.47x10 ⁻⁸ (5)	1.85x10 ⁻¹² (5)	162,000,000 ⁵			
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	390.87 ⁵	2.65x10 ⁻⁵ (5)	9.47x10 ⁻⁸ (5)	1.94x10 ⁻⁶ (5)	162,000,000 ⁵			
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	356.42 ⁵	1.53x10 ⁻⁴ (5)	3.96x10 ⁻⁷ (5)	2.61x10 ⁻⁶ (5)	36,300,000 ⁵			
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	425.31 ⁵	2.4x10 ⁻⁶	7.5x10 ⁻¹⁰ (5)	1.75x10 ⁻⁴ (5)	158,500,000 ⁵	63,100,000 ¹⁰	2.58 ¹² *	512 Fathead minnows (10)
2,3,7,8-Tetrachlorodibenzo-p-dioxin	312.98 ⁹	3.17x10 ⁻⁵ (9)	6.4x10 ⁻¹⁰ 9	5.4x10 ⁻²³ 9	1,600,000	2,000,000 (lake Ontario sed.) ⁹	1.827 (25°C)	5,370 fish (9)
Heptachlorodibenzo-p-dioxins (total)	425.31 ⁵	1.9x10 ⁻³ (5)		2.18x10 ⁻⁵ (5)	60,260,000 ⁵			
Hexachlorodibenzo-p-dioxins (total)								
Octachlorodibenzo-p-dioxin	459.76 ⁵	7.4x10 ⁻⁸ (5)	8.25x10 ⁻¹³ (5)	6.74x10 ⁻⁶ (5)	158,500,000 ⁵	79,400,000 ¹⁰	2.65 ¹² *	2,238 Fathead minnows (10)
Octachlorodibenzo-p-dioxins (total)								
Pentachlorodibenzo-p-dioxins (total)								
Tetrachlorodibenzo-p-dioxin								
Furans								
1,2,3,4,6,7,8-Heptachlorodibenzofuran	409.31 ⁵	1.35x10 ⁻⁶ (5)	2.01x10 ⁻⁸ (5)	6.28x10 ⁻⁶ (5)	83,200,000 ⁵		1.24 ¹² *	
1,2,3,4,7,8,9-Heptachlorodibenzofuran	409.31 ¹⁰		4.65x10 ⁻¹¹ (25°C) ¹⁰		7,940,000 ¹⁰	5,012,000 ¹⁰	1.24 ¹² *	
1,2,3,4,7,8-Hexachlorodibenzofuran	374.87 ¹⁰	8.25x10 ⁻⁶ (22.7°C) ¹⁰	2.85x10 ⁻¹⁰ (25°C) ¹⁰		50,100,000 ¹⁰	25,100,000 ¹⁰		
1,2,3,6,7,8-Hexachlorodibenzofuran								
1,2,3,7,8,9-Hexachlorodibenzofuran								
1,2,3,7,8-Pentachlorodibenzofuran	340.42 ⁵	8.73x10 ⁻⁴ (5)	3.46x10 ⁻⁷ (5)	1.14x10 ⁻⁵ (5)	6,166,000 ⁵			
2,3,4,6,7,8-Hexachlorodibenzofuran								
2,3,4,7,8-Pentachlorodibenzofuran	340.42 ⁵	2.35x10 ⁻⁴ (23°C) ⁵	3.46x10 ⁻⁷ (5)	1.14x10 ⁻⁵ (5)	8,320,000 ⁵	25,100,000 ¹⁰		5,012 Guppies (10)
2,3,7,8-Tetrachlorodibenzofuran	305.98 ⁵	4.19x10 ⁻⁴ (23°C) ⁵	1.53x10 ⁻⁶ (5)	1.54x10 ⁻⁵ (5)	3,400,000 ⁵	31,600,000 ¹⁰	1.14 ¹² *	6,607 Guppies (10)
Heptachlorodibenzofurans (total)								
Hexachlorodibenzofurans (total)								
Octachlorodibenzofuran	443.76 ⁵	3.85x10 ⁻⁶ (40°C) ⁵	5.47x10 ⁻⁹ (5)	4.66x10 ⁻⁶ (5)	398,000,000 ⁵	5,600,000 ¹⁰	1.26 ¹² *	588 Guppies (10)
Pentachlorodibenzofurans (total)								
Trichlorodibenzofurans (total)								
Tetrachlorodibenzofurans (total)								
Octachlorodibenzofurans (total)								

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